A STUDY OF THE INTERNAL STRUCTURE OF APPLE LEAVES OF VARIETIES, SPECIES AND HYBRIDS, WITH SPECIAL REFERENCE TO GROWTH AND FRUITFULNESS

BY

CHARLES JOHN BIRKELAND

B. S., Michigan State College, 1939

M. S., Kansas State College, 1941

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN HORTICULTURE
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UNIVERSITY OF ILLINOIS, 1947

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A STUDY OF THE INTERNAL STRUCTURE OF APPLE LEAVES OF VARIETIES, SPECIES AND HYBRIDS, WITH SPECIAL REFERENCE TO GROWTH AND FRUITFULNESS

In recent years a large number of investigators have studied the photosynthetic activity of apple leaves and the effect of certain spray residues on the rate of photosynthesis. In general, these studies show that the residues on the two surfaces of the leaves not only reduce photosynthetic activity, but also that the stronger the spray material, the greater the reduction in the rate of photosynthesis.

The importance of the leaf in relation to fruit bud formation and the relationship between leaf area and fruit size has been demonstrated by numerous workers, and a large number of investigators have reported on the relationship between yield and other growth characteristics such as shoot and spur length, and trunk circumference.

That a more extensive intercellular space in apple foliage is reflected in greater photosynthetic activity has been set forth by some workers, who, in fact, conclude that the extent of the internally exposed surface of apple leaves is more important than the chlorophyll content as a factor partially governing photosynthetic activity. Further studies on the relation between the internal structure of the leaf and its activities showed that varieties differed in the ratio R of the internally exposed surface to the externally exposed surface, that this value was greater in field-grown apple leaves than in those grown in the greenhouse. It was also found that repeated application of certain spray materials reduced this value in both the greenhouse and field. The spray materials were found to shock or check normal cell development in apple leaves with each application throughout the growing season; mild sprays did not exert so great

a dwarfing effect as did the stronger materials.

The total depth of palisade tissue was closely correlated with the R value and could be used to estimate this ratio, thus saving approximately 90 per cent of the time needed in the standard calculations. This work suggested that assuming the R value to be an important factor in photosynthetic activity, the lower ratio of York may be offered as one of the factors contributing to the biennial bearing habit of this variety in the Missouri Valley as well as in the Shenandoah Valley where this variety is grown so extensively. It was also suggested from these studies that this factor may be used for determining vigor of seedling trees while still in the nursery, and thus save several years in selection.

In view of the above investigations of the relationship of the internal structure of apple leaves and their photosynthetic behavior, along with environmental and varietal differences, it was proposed to make a further study of the genetic significance of this situation. At the University of Illinois there was presented the opportunity of working with several varieties and species, and with one hundred nineteen seedlings from a Jonathan X Yellow Transparent cross, some of which had come into bearing. It was suggested that if the internal structure of the leaves was related to fruitfulness, this factor may become a valuable tool for the fruit breeder when working with the tree fruits in which there is such a slow turnover of the generations.

Materials and Methods

From June 18, 1946, to June 29, 1946, ten to twenty apparently uninjured leaves of an average size for the tree were collected from ten varieties, one hundred nineteen hybrid seedlings from a Jonathan X Yellow Transparent cross, and from twenty one species. The leaves selected were from near the middle of the new shoots which were from six to twelve inches long. The portions of the leaves used for microscopic study were located near the midrib and

midway between the basal and apical regions. The marginal and midrib portions of each leaf were discarded. Only one piece, about one by three centimeters, was taken from a single leaf.

These leaf pieces were placed in a one per cent chromo-acetic acid killing and fixing solution and evacuated. After leaving them in the killing and fixing solution for 24 hours, they were washed, dehydrated with tertiary butyl alcohol, and imbedded in paraffin. The leaves were placed five deep in the paraffin blocks, which enabled one to section them five at a time for mounting on slides, thus permitting a much more rapid study of the material.

One set of slides was made from each block of leaves. A set of slides consisted of one slide with cross sections of five leaves and one slide with tangential sections of one leaf. All sections were eight microns thick. They were stained with one-half of one per cent safranine 0 in 50 per cent alcohol, and mounted in balsam. Three to five sections were placed on each slide.

In order to determine the internally exposed surface of a leaf, drawings were made from the slide at a high magnification. When these drawings were measured and the magnification determined, the amount of internally exposed surface could be readily calculated. The calculations were made in a similar manner to those described fully in the Kansas Agricultural Experiment Station Technical Bulletin 53.

Observations

Varieties. The varieties for this study were chosen because of their importance commercially and their differences in adaptability. They ranked in the same order in relation to one another as those previously studied in a different region, and the differences between varieties were statisically significant, except McIntosh whose leaves were

extremely variable.

Species. The species were chosen because of their interest to the plant breeder. As with varieties, there was more variability between species than between leaves within a secies, again indicating genetic control of leaf structure. A few species which are beyond their natural range in Illinois were vary variable, showing that environmental factors become more influential when a tree is far from its natural habitat.

Hybrids. A study of the progeny of a Jonathan X Yellow Transparent cross made in 1932 was undertaken to determine whether there was any correlation between leaf structure or growth and yield. Estimates of the yield were made on the trees under study just before harvest, and the trees were grouped into five classes—those with no fruit, a light crop, one-half bushel, one bushel, and a full crop. Growth records were taken during the dormant season, including heighth of tree, greatest spread, and trunk diameter.

An analysis of variance showed a definite correlation between yield and growth as determined by heighth, trunk diameter and spread of tree. Each of these measurements increased progressively with each increase in yield.

There was no significant difference in the depth of palisade cells among the yield classes of light fruit, one-half bushel, and one bushel, so these three classes were grouped together under light fruit. An analysis of variance was then made of the length of palisade cells in relation to yield. The variability or mean square between yield groups was highly significantly greater than the variability between trees within these groups. Therefore, the mean differences found were related to the lack of fruit or productiveness of the tree.

The total depth of palisade was highly correlated with the R value, thus making it possible to estimate the extent of internally exposed surface from the palisade depth.

Discussion

Certain generalizations may be made from the observations herein reported with respect to the relationships between the internal structure of the leaves and the production potentiality of the tree.

It was found for the most part that species and varieties differed significantly from one another with respect to depth of palisade. A few individuals were extremely variable but they were far from their natural habitat in Illinois. These results indicate that while under most conditions the internal structure of the leaf is primarily determined by genetic factors and modified to a certain extent by environmental factors, if the tree is grown beyond its natural range of adaptation the environmental factors become more influential and induce extremes in variation.

Observations made on the one hundred nineteen hybrid trees from the Jonathan X Yellow Transparent cross showed that productivity was correlated directly with growth factors, the trees not yet bearing being the smallest, and those with a full crop being the largest.

The three groups having a light crop possessed a greater total depth of palisade tissue than the trees which had never borne fruit, indicating that leaf structure and leaf area are correlated with productivity. The trees having a full crop showed less palisade development than those with a light crop, though more than those with no fruit. This would indicate that though a greater depth of palisade tissue is correlated with productivity and earliness of coming into bearing, a full crop competes with the leaves for nutrients to such an extent that the internal structure is reduced to less than in those trees having a light crop.

Since growth of tree as measured by trunk diameter, heighth, and spread, and total depth of palisade tissue in the leaf, are both correlated with earliness of coming into bearing and productivity, these should be characteristics in

a young tree which could be used to foretell its future vigor and productivity. Vigor of growth is cumulative, however, and difficult to measure in a young tree, due to variability in the size of trees in the nursery as affected by environmental factors such as location and cultural treatment. In fact it has been found that there is no very positive correlation between the size of a two year old tree in the nursery and a ten year old tree. The total depth of palisade, however, is approximately the same in a one year old tree as in a mature tree, and is much less variable in the young tree. Therefore, the depth of palisade actually gives a truer picture of the potentialities of the tree in the nursery than on the more mature tree after environmental factors have had time to gain expression.

It may be concluded from the above data that in apple breeding experiments a large number of seedling trees could be eliminated from the nursery because they do not possess the gene complex which would produce a vigorous productive tree. This would assure the breeder of two important characteristics for a new variety, namely vigor of growth and productivity. The breeder could then devote more time to other desirable characters such as disease resistance, quality, keeping quality, and color in a population from which the low producing trees and those which would come into bearing late, if at all, were elminiated.

VITA

Charles John Birkeland was born at Warwick, North Dakota, on April 16, 1916. He was graduated from Devils Lake High School in 1934.

He entered North Dakota State College in September, 1935, and transferred to Michigan State College in January, 1938, from where he received the degree of Bachelor of Science with honor with a major in horticulture in March, 1939.

In July, 1939, he was appointed Graduate Research Assistant in Horticulture at Kansas State College, where he received the degree of Master of Science in 1941. He was then appointed full time Assistant in Horticulture.

He enlisted in the Naval Reserve in May, 1942, and was called to active duty in January, 1943. He was commissioned an Ensign in May, 1943, at the United States Naval Reserve Midshipman's School, Notre Dame, Indiana. He served as a Port Director Operations Officer at San Francisco and Okinawa, with temporary duty stations at Port Hueneme, Los Angeles, and Pearl Harbor. He was released to inactive duty as a Lieutenant (senior grade) in March, 1946. In February, 1946, he enrolled in the Graduate School of the University of Illinois. In September, 1946, he was appointed an Assistant in Pomology in the Department of Horticulture.

He was elected to Alpha Zeta and the Lincoln Debate Club in 1937, Phi Kappa Phi, Associate of the Society of the Sigma Xi, and Gamma Sigma Delta, the Honor Society of Agriculture in 1941. He was awarded the Research Prize of the Kansas State Chapter of the Society of the Sigma Xi for his Master's Thesis in 1941, and in 1942 was elected a full member of the Society of the Sigma Xi.

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